SILVICS of LODGEPOLE PINE

Botanical range of lodgepole pine.

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SILVICS OF LODGEPOLE PINE

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FOREWORD

The SILVICS OF LODGEPOLE PINE is the fourth publication in the series of seven silvics manuals being published by the Intermountain Forest and Range Experiment Station as part of a larger project sponsored by the U.S. Forest Service. Forest Service Experiment Stations over the Nation are issuing similar bulletins on many important North American tree species. Eventually a single publication that will include the entire series will be issued by the U.S. Forest Service.

Information in this publication is based on selected references and unpublished research data through 1957. The author will appreciate having any omissions or apparent misinterpretations called to his attention.

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Lodgepole pine (Pinus contorta) (38)[2/] has a wide geographic range. It extends from Alaska and interior Yukon Territory south to northern Baja California and east to the Black Hills of South Dakota. The northern limit is at about 64° N. latitude on the divide between the Klondike and McQuesten Rivers; the southern limit is at about 31° N. latitude in the northern part of Sierra San Pedro Martir in Baja California (58).

Some taxonomists distinguish two varieties of this pine: Pinus contorta var. contorta, a coastal form, and Pinus contorta var. latifolia, an inland or mountain form. The coastal form is the low, scrubby tree of the Pacific coast from southeastern Alaska to northern California, while the inland form is the taller tree of the mountains from Yukon southeast to Colorado (38). The reproductive organs of both forms are practically identical (29) and for a long time morphological differences were considered unreliable. Variations were described as largely environmental (18). Recently a detailed study (14) of the geographic variation of this pine has shed new light on its taxonomy, and it has been proposed that the species be divided into four subspecies. This taxonomic division is described later under "Races and Hybrids."

The interior form has the greater commercial importance today, especially in Montana, Oregon, Idaho, Utah, Wyoming, and Colorado, and in British Columbia and Alberta, Canada.

HABITAT CONDITIONS

CLIMATIC

It is difficult to generalize about the climate in which lodgepole pine grows. The interior form in the Rocky Mountain-Intermountain area usually is found in a cool, relatively dry climate having a wide seasonal range in temperature. In the Sierra Nevada the inland form occurs in zones of high precipitation. The coastal form grows best in rather cool, moist zones having a relatively narrow seasonal range in temperature.

In most of the Rocky Mountain-Intermountain area where the interior form grows, summers are fairly dry and precipitation is likely to be deficient for short periods during the growing season. Best development occurs where annual precipitation is 21 inches or more, but extensive stands are found where

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2/ Underlined numbers in parentheses refer to Literature Cited.

precipitation is only 18 inches (39). Annual snowfall generally varies from 11 to 120 inches, but may reach as much as 250 inches or more and lie on the ground until late spring (41). The growing season is generally short (60 to 100 days), and frosts may occur every month in the year. Average July temperatures generally are between 55° and 63° F. Temperature extremes of about 100° F. and -55° F. occur for short periods (39).

An example of extreme variation in rainfall where lodgepole pine grows is found in the northwestern part of its geographic range. Near Atlin Lake in northwestern British Columbia where the inland form grows the average annual rainfall is only 11 inches; less than 200 miles south of this area on Baranof Island off the coast of Alaska the coastal form grows where the average annual rainfall is more than 160 inches (14).

EDAPHIC

Lodgepole pine is not exacting in its soil requirements and grows on a wide variety of soils. The interior form does well on moderately acid, sandy, or gravelly loams that are moist, light, and well drained (29).

In the region where lodgepole pine has its greatest commercial importance, good stands are found on soils of granitic, shale, or sandstone origin. Extensive stands also occur on soils derived from coarse-grained lavas. In the United States, soils derived from limestone or fine-grained igneous rocks generally do not support good stands (4). The former are too dry, and the latter break down into clays that are too poorly drained (12). However, in Alberta, Canada, stands of medium to good productivity commonly occur on well-drained, calcareous tills having a silty loam or clay loam texture.[3/]

In the Cascade Mountains of Oregon and Washington and the Sierra Nevada in California, lodgepole pine occurs mainly on wet flats and poorly drained soils. In the Sierra Nevada the incidence of small lodgepole pine stands within ponderosa pine (Pinus ponderosa) stands is determined by the presence of a clay pan impervious to moisture under the lodgepole (33). Similarly, in eastern Oregon, soils with underlying hardpan, which helps retain soil moisture in the root zone, support lodgepole pine to the exclusion of ponderosa pine (49).

In central Oregon lodgepole pine occurs mainly on level sites having a relatively high water table or on poorly drained soils. However, at elevations above the 5,000- to 6,000-foot zone, it occurs on sites that are well or excessively well drained. In these areas the pattern of occurrence is believed to be created by past fires.[4/]

In the Blue Mountains or northeastern Oregon and southeastern Washington, occurrence is nearly always upon volcanic ash (pumicite) soils or alluvial material overlying residual basaltic soils at elevations between 3,000 and

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3/ Written communication from Canada Department of Northern Affairs and National Resources, Calgary, Alberta, dated October 15, 1956.

4/ Written communication from Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, dated October 23, 1956.

7,000 feet (65). These soils are much deeper than the residual soils of the area and afford the greater moisture supply necessary for aggressive lodgepole pine growth.[5/]

Pure scrubby stands of the coastal form are found in peat bogs or muskegs in southeastern Alaska and British Columbia and in the Puget Sound Basin of western Washington. Similar stands occur farther south on dry sandy and gravelly sites near the Pacific Ocean (29).

PHYSIOGRAPHIC

The altitudinal range of lodgepole pine extends from sea level up to 11,500 feet. The coastal form is restricted to elevations from near sea level up to about 2,000 feet. The inland form occurs from 1,500 feet to 11,500 feet elevation.

In the more southerly latitudes lodgepole pine grows at progressively higher elevations. In Yukon Territory, at the northern part of its range, lodgepole is found between 1,500 and 3,000 feet elevation; farther south in Montana, east of the Continental Divide, between 4,500 and 9,000 feet; in northern Wyoming between 6,000 and 10,500 feet; and in southern Wyoming and Colorado between 7,000 and 11,500 feet.

Lodgepole pine generally grows in mountainous regions, but may be found under a great variety of topographic conditions. It grows especially well on gentle slopes and in basins, but many good stands are found on rough and rocky terrain (59). On steep slopes and ridges it grows on bare gravel (39). Northern and eastern aspects are favored over western aspects. Southern aspects are least favorable except in sheltered locations.

BIOTIC

Lodgepole pine is a major timber species in the Canadian life zone (43) of both the Cascade-Sierra and Rocky Mountain ranges. The type is part of the forests of the interior middle elevations and is considered pure when there are no significant amounts (more than 20 percent) of either western white pine (Pinus monticola) or ponderosa pine (57). However, minor numbers of several species may be present. The coastal form is not recognized as a distinct type.

This pine is represented in 11 other cover types of western North America (57). At high elevations in the mountains it is a minor component in the Engelmann spruce (Picea engelmannii)--subalpine fir (Abies lasiocarpa), red fir (A. magnifica), and whitebark pine (Pinus albicaulis) types. At middle elevations in the interior it is a minor component of the following types: interior Douglas-fir (Pseudotsuga menziesii var. glauca), larch (Larix occidentalis)--Douglas-fir, ponderosa pine--larch--Douglas-fir, western white pine, Rocky

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5/ Ibid.

Mountain juniper (Juniperus scopulorum), and aspen (Populus tremuloides). It is also found in the western juniper (J. occidentalis) type, which occurs at low elevations in the interior, and in the Jeffrey pine (Pinus jeffreyi) type.

Although dense lodgepole pine forests have a dearth of minor flora, certain shrubs and occasionally herbs typify the stands when they are not heavily overstocked and where they do not occur in a transition zone between other timber types. Following are lists of these plants in the principal localities where lodgepole pine can be defined as a true cover type:

a. Cascade Range in Washington and Oregon--Xerophyllum tenax, Pachistima myrsinites, Vaccinium spp., Arctostaphylos nevadaensis, Amelanchier spp. (24).

b. Sierra Nevada in California--Prunus emarginata, Arctostaphylos nevadaensis (34).

c. Bitterroot Mountains in Idaho--Amelanchier spp., Prunus emarginata, Holodiscus discolor, Rosa spp., Symphoricarpos spp. (19), Xerophylum tenax, Vaccinium myrtillus (36).

d. Central Montana--Vaccinium scoparium, Cercocarpus ledifolius (36), Calamagrostis rubescens (39).

e. Southern Idaho, Utah, and Wyoming--Calamagrostis rubescens, Juniperus communis, Juniperus sibirica, Pachistima myrsinites.

f. Central Rocky Mountains in Colorado--Shepherdia canadensis, Vaccinium scoparium.

Closely uniform, mature stands of lodgepole pine do not favor the presence of vertebrate animals. When stands are opened up by fire or cutting, the usual faunal influx common to many forest types follows. Squirrels, chipmunks, mice, and birds destroy great numbers of lodgepole pine seeds, but their effect on inhibiting reproduction appears to be insignificant because of the frequent heavy cone crops and high germinative capacity of the seeds. Seed losses to rodents and birds could become a factor of concern on cutover areas where cones are predominantly nonserotinous.

LIFE HISTORY

Most of the known facts about the life history of lodgepole pine were derived from observations and studies on the inland form and primarily from the Intermountain and Rocky Mountain regions. This form is not only the more widespread of the two, but is by far the more important commercially.

Little emphasis is placed upon the coastal form of lodgepole pine in present day forest management in the United States. The following statements, therefore, apply mainly to lodgepole pine in its range of greatest commercial importance in this country and in Canada; namely, northern Colorado, western and southern Wyoming, western and central Montana, northern Utah, southern Idaho, southern Oregon, western Alberta, and southern British Columbia.

SEEDING HABITS

Flowering and fruiting.--Little specific information is available regarding flowering of lodgepole pine in different parts of its range. Time of pollen shedding shows both annual and geographic variation. Suggested dates for collecting pollen for breeding work correspond closely with the dates when shedding begins (21). Three-year records at latitude 39° N., longitude 120° W. at 6,000 feet above sea level near Lake Tahoe, California, show the earliest collection date for pollen from the inland form to be June 5, the latest date July 8, and the mean date June 22. The mean collection date for pollen from the coastal form in a single year's observations at latitude 39° N., longitude 124° W. near Point Arena, California, was June 9.[5a/]

Cones from the current year's crop (inland form) mature in August and September and in September and October (coastal form) (66). When they are fully ripe the scale tips are shiny and a light brown color; their inner portion is a bright purple brown (58). The cones are subcylindric-to-ovoid-shaped, small (3/4 to 2 inches long), and frequently have asymmetrical bases.

Most of the viable seed is borne on scales nearest the tip of the cone, except for the first few scales. The extreme basal scales and all undeveloped scales are generally barren. Usually the seeds are entirely in the upper half of the cone (5).

Fertile seeds of good quality are normally black or slightly grayish because of the presence of minute excreta of resin. A brown color denotes incomplete seed development and therefore low vitality. Hollow seeds invariably are almost white, or black with large white blotches. Fertility is not related to seed size (5).

During their development, conelets frequently tend toward one-sidedness. This results in a flattening or even a concavity of the undeveloped side. Failure of pollen to reach the surface of the conelet closely appressed to a stem or branch, and lack of sufficient light in this area for physiological functions to progress, have been given as possible explanations (5).

A recent study (14) shows that maximum cone asymmetry is associated with large angles of cone attachment to the branches and with high cone specific gravity. This is especially true of the asymmetrical cones from trees growing in the Rocky Mountains. Cones from trees in the Sierra Nevada, which have a low specific gravity and which are attached to the branches at approximately right angles, have maximum symmetry.

5a/ Additional dates of flowering and pollen shedding, both for natural stands and planted trees, are available in unpublished form in files at the Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Seed production.--Cones bearing viable seed are produced at an extremely early age--in open-grown stands by trees from 5 to 10 years old; in more heavily stocked stands by trees from 15 to 20 years old. Seed from trees less than 10 years old have shown a germination percentage as high as seed from mature trees. Commercial cone-bearing ages are from 50 to 200 years (39).

Lodgepole pine is a prolific seed producer. Good crops occur at 1- to 3-year intervals with light crops intervening (5, 8, 40, 66).

The number of fully developed seeds per cone varies widely, from as few as 1 or 2 to as many as 50. In one study an average of 26 seeds per cone was determined on nine national forests in Colorado and Wyoming (39). Another study showed an average of 40 for large lots of cones (5). Unpublished results of several small tests in Idaho and Montana show averages between 20 and 25 seeds per cone.

Cone production per tree varies; consequently, the number of seeds per tree also varies. Averages of 50,000 and 21,000 seed per tree from old and new cones together were found on areas in Idaho and Colorado, respectively (13). Obviously seed yields per acre vary considerably and can be estimated only in a general way. For example, an annual yield of 320,000 seed per acre was estimated for an area in central Colorado and 73,000 per acre for an area in southern Wyoming for the 10-year period, 1912 to 1921 (5).

Geographic differences in the closed-cone habit of lodgepole pine have been recognized. In most coastal populations serotinous cones are uncommon. Notable exceptions occur on the Mendocino white plains in northern California (42) and sporadically in areas not in the immediate vicinity of the coastline, mainly in the low mountains of the northwestern corner of California and southwestern corner of Oregon (14).

Throughout much of the inland distribution cones are generally serotinous, but even here many exceptions are found. Whereas in the Rocky Mountain and Intermountain regions the closed-cone habit is widespread, in the Sierra Nevada cones open at maturity (22, 14). Trees in the Oregon Cascades, the eastern Siskiyou Mountains, and in southern and Baja California also reportedly have nonserotinous cones (14). Other areas where cones have been reported to be mainly nonserotinous are the Deschutes Basin in Oregon (67) and the Blue Mountains in northeastern Oregon (65).

In stands that have closed cones, individual trees may have both serotinous and nonserotinous cones, and a preponderance of either kind (16).

The closed-cone habit has considerable silvicultural significance. Where serotinous cones are abundant, as in the Rocky Mountain region, a large quantity of sound seed is available for release following fire or cutting. One study showed the maintenance of an amount equal to about three times the average current crop in closed persistent cones (5). Germinative potential declines slowly and much of this seed remains viable for a long time. Viable seeds have been extracted from serotinous cones 75 to 80 years old (41), and a few seeds were germinated from 150-year-old cones imbedded in wood (44).

Closed cones of lodgepole pine in slash. These cones are the principal source of seed for a new stand following cutting operations.

The basic reasons for "serotiny" in lodgepole pine, its exact geographic distribution, and the degree of its occurrence within a stand must be dealt with area by area. The presence of serotinous cones cannot be taken for granted.[6/]

Although certain vertebrate animals, insects, birds, and subfreezing weather may exact a toll on the cone crop each year, these agencies have a negligible silvicultural effect on cone crops.

Seed dissemination.--Lodgepole pine seeds are small (approximately 102,000 seeds per pound for the inland form and 135,000 per pound for the coastal form). In still air the seeds fall at an average rate of 2.7 feet per second. Their average weight is 0.0055 gram (55).

Seed from standing trees are disseminated throughout the year but not at a uniform rate. In Montana in a pure, even-aged, overmature stand in 3 out of 4 years, only 20 percent of the yearly crop disseminated was released during August and September. Sixty-two percent was shed during October to June of the following year, and 18 percent during June and July (9).[7/] In an uncut overmature stand over a 4-year period, sound seeds were released at the rate of 17,000 per acre per year. On the average in each year 80 percent of the seed came down prior to the following growing season.

6/ For more complete discussions of the closed cone habit of lodgepole pine, see Critchfield (14) pp. 60-61 and 66-67; Crossley (16); and Clements (13).

7/ In 2 years of record on the Pringle Falls Experimental Forest, Oregon, most of the seedfall occurred during September and October; only about 10 percent occurred between November 1 and June 1 of the following year. (Written communication from E. L. Mowat, Bend, Oregon, dated April 23, 1956.)

In the subalpine forest region of Alberta, Canada, during 3 years of study in a 60-year-old stand, maximum annual seedfall occurred over a 4- to 5-week period and climaxed the first week of October; however, small amounts were released continuously throughout the year (15).

Although wind is normally the principal agent in seed dissemination, it is not important in dispersal so far as management of the species is concerned (64). Seed dissemination by wind suitable for restocking open areas is seldom beyond 200 feet from the parent trees (9, 41).

The most important seed dissemination from a management standpoint occurs following logging operations. This dispersal comes from cones attached to the slash and from cones knocked from the slash and scattered over the forest floor. Maximum seed release from this source takes place after the first year of cone exposure to the natural elements (9); some further release occurs for as long as 6 or more years (61).

Fire is not a requisite for seed release from closed cones stored in the slash (6, 60). Usually the resin that seals the scales together melts at 113° F. (45° C.) (13). When this occurs the scales are free to flex and spread apart. This can occur under natural conditions without fire when enough heat reaches the cone surface through radiation, convection, or conduction (17). On the other hand, fire may hasten the opening of some cones that are not suitably positioned for the resin bond to be melted or softened by solar heat.

The relationships between cone opening, seed availability, and initial stand density suggest that the relative amounts of seed available for release may be controlled by careful disposal of slash with heavy machinery and fire used judiciously. Burning slash windrows, concentrations, and dozer piles that are one-twentieth acre or less in area and that occupy not more than 25 percent of the total area cut has little detrimental effect on regeneration (9).

VEGETATIVE REPRODUCTION

Lodgepole pine has been grafted successfully on mature ponderosa pine (46) and on Scotch pine (Pinus sylvestris) (30). It does not reproduce naturally by sprouting.

SEEDLING DEVELOPMENT

Establishment.--Lodgepole pine seed generally has persistent vitality and a high germinative capacity without pretreatment. Although stratification is not needed, it does hasten and improve germination (66).

The viability of seed in closed cones in the slash is affected by cone position. In one study (61) in 6-year-old slash, seed from cones above ground had about twice the germinative energy and germinative capacity of seed from cones on the ground.

Most viable seed germinate in the spring following dispersal, but a small amount may germinate a year later because of the occasional embryo dormancy exhibited by this species (66). Fluctuating temperatures between 47° and 78° F. favor germination (5). For subsequent growth and development, soils having a slightly acid reaction produce best.

Best germination occurs in full sunlight and on mineral soil or disturbed duff that is free of competing vegetation. For this reason a clear cutting system is most desirable for reproduction of this species. On many areas, however, lodgepole pine has become established in the shade of lightly cut or uncut stands. Such reproduction may persist for many years, but it is rather unusual among intolerant tree species.

Early growth.--Lodgepole pine seedlings are frail in appearance and root slowly (5). A taproot is formed. In one study (25) taproots were found not to persist beyond the juvenile years. However, more recently it has been shown that the taproot is maintained but may be bent, stunted, atrophied at its extremity, or obscured by other roots in the system (31). The lateral roots develop horizontally outward compared to those of ponderosa pine, which grow obliquely downward (25). Later, especially on deep soils, the laterals may develop deep sinkers, giving the root system a heart-shaped form (31). Light sandy soils that hold most of their moisture at considerable depth favor deep rooting. Furthermore, these light soils do not, after denudation, encourage a heavy growth of herbaceous vegetation (5).

Seedling establishment and early survival on south slopes benefit from partial shade, which retards losses of soil moisture and protects from heat due to prolonged, direct insolation.

Early growth rates are good but they vary with locality and site. On the Deerlodge National Forest, Montana, in typical fully stocked stands on slightly better-than-average site, 20-year-old dominant trees average 1.9 inches d.b.h. and 12 feet in height.

Lodgepole pine frequently regenerates too abundantly. Overstocking often results in growth stagnation at extremely early ages. A striking example of this was found on a burn in Montana where a single milacre quadrat was stocked at the rate of 765,000 10- to 11-year-old trees per acre (37). These trees ranged in height from 4 to 25 inches. Other studies on burns in Montana report plots having as many as 300,000 1-year-old seedlings per acre, and in 8-year-old stands up to 175,000 trees per acre, averaging about 2 feet high. In Colorado 10 small sample plots in a 22-year-old stand established after a fire showed an average of 44,000 trees per acre (39). The tendency of this species toward overstocking and stagnation is therefore probably the most extreme of any tree species on the North American continent.

Seasonal growth data on lodgepole pine are available from the east slope of the Rocky Mountains in Alberta and the Sierra Nevada in California only. In the subalpine forest of Alberta leader growth of saplings for a 4-year period consistently started in early May and continued for 12 weeks. However,

within each growing season the distribution of growth differed widely from year to year. Trends of weekly leader elongation were similar but rates differed according to aspect. Growth on a south aspect was consistently greater than on other aspects, and was directly related to corresponding mean weekly temperatures, except toward the end of the growing season (32).

Eight years of record from the west slope of the Sierra Nevada, at about 5,200 feet elevation, show that lodgepole pine begins height growth earlier than its common tree associates in this locality. For example, 88 percent of the seasonal height growth of lodgepole pine was completed before white fir started height growth. About 60 percent of the seasonal height growth of lodgepole pine was completed at the time of needle emergence from the fascicle sheath, and all of it was completed before needle growth ceased. Lodgepole pine also ceased height growth before any of its tree associates in this region (23).

SAPLING STAGE TO MATURITY

Growth and yield.--Lodgepole is one of the smaller pines and shows remarkable range in stand density and striking reactions to both density and environment (56, 62). For example, in the Rocky Mountains one study in 100-year-old stands of varying density showed a maximum yield of 20,000 board feet per acre with 800 trees; yield fell off rapidly to less than 1,500 board feet when the number of trees increased to 1,800 (41). Similar effects on the cubic-foot yield of the stands and upon the average height and diameter of the trees were shown. Stagnated stands 70 years old may have as many as 100,000 trees per acre, averaging only 4 feet in height and less than 1 inch in diameter at the ground.

On the average, yields of 12,000 to 15,000 board feet per acre are considered good in old-growth Rocky Mountain lodgepole pine. Yields of 20,000 to 25,000 board feet per acre are exceptional.

The stands that occur from Glacier National Park along the Continental Divide to south central Montana appear to differ from those in Colorado in several ways. Aside from differences in composition of the understory, the Montana trees are generally smaller. Yields per acre are also generally lower in Montana than in Colorado.

The low-elevation lodgepole that grows in northeastern Washington and adjacent areas in northern Idaho has a faster growth rate and dies earlier than the lodgepole pine at higher elevations in Montana. These stands generally start breaking up at 80 to 100 years.

Lodgepole pine does not prune well naturally. In open-grown stands branches are retained nearly to the ground. In dense stands the clearboled appearance of the trees is often misleading. Partial pruning of the bole for 10 to 25 percent of its length is common; however, pruning often does not progress to complete elimination of the basal portion of the branches.

Sizes attained vary according to locality. Within the main lodgepole pine region most trees at 140 years are 7 to 13 inches in diameter and 60 to 80 feet tall (41). In the Blue Mountains of Oregon at 100 years of age trees average 12 inches in diameter and 70 to 80 feet in height (28). At 100 years of age trees in the Sierra Nevada reach average diameters of 15 to 18 inches and average heights of 90 to 100 feet (28).

Trees of the coastal form vary greatly in size at given ages; mature trees from 6 to 20 inches in diameter and 20 to 40 feet tall occur. On a small plateau a few miles wide along the coastal plain of Mendocino County, California, an extreme condition is found where mature lodgepole pine is little more than a canelike dwarf 2 to 5 feet high (34). This dwarfed condition is associated with a highly acid hardpan soil.

The largest tree of this species on record is 19 feet in circumference at 4½ feet above ground and is 106 feet tall (1). It is located outside of the main lodgepole pine region on the Sierra National Forest in California.

The oldest lodgepole pine stand on record was found on the Beaverhead National Forest in Montana (39). Its age in 1915 was 450 years. Individual trees as old as 600 years have been reported (14).

A 60-year-old stand of pure, even-aged lodgepole pine.

In fully stocked, pure, even-aged stands on medium sites in Montana (Deerlodge National Forest) average heights and diameters of the main stand 7 inches d.b.h. and larger are as follows:

Age (Years)	Height (Feet)	D.b.h. (Inches)
40	33	7.0
60	54	7.8
80	61	8.4
100	65	8.8
120	69	9.2
140	71	9.6
180	75	10.0

In stands of this kind the mean annual increment in cubic feet to a 2½-inch top culminates between 70 and 90 years, and in board feet, measured to a 6-inch top, at 130 years (40).

Since some localities have better average sites than those from which the above data were derived, rotation ages for fully stocked stands probably would be between 70 and 90 years for greatest cubic-foot return, and between 120 and 140 years for maximum large-size material. Such stands without thinning should yield 8,000 to 12,000 board feet per acre at rotation age.

The cubic-foot volume in fully stocked stands on some of the best sites in British Columbia (Site Index 80 at 80 years) for trees 6 inches and larger in diameter to a 3-inch top is as follows (11):

Age (Years)	Volume per acre (Cubic feet)
40	1,560
60	4,200
80	6,200
100	7,550
120	8,450
140	9,000

Climax position.--Ecologically lodgepole pine stands may be grouped into two categories: (1) subclimax stands and (2) seral stands.

1. Subclimax stands: In these stands lodgepole pine is being held indefinitely on the area by either natural factors other than climate or artificial factors.[8/] Stands of this kind exist in their present state because of isolation from effective seed supplies of species that have the natural

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8/ In some places stands of this kind have occupied the site so long that they appear like climax plant communities. Where this occurs they may be true climax stands and probably will be managed as such by silviculturists.

potential for replacing them. This condition was initially brought about by fire. Both fire and present soil-water relationships play an important part in its maintenance. These virtually stable tree communities are usually pure lodgepole pine, but frequently minor amounts of other species are present.

2. Seral stands: In these stands lodgepole pine is only a temporary occupant of the site, as evidenced by one or more of the following conditions:

a. appreciable amounts of advance reproduction of other species
b. mixed composition of the overstory
c. pure lodgepole pine of limited extent within stands of climax species or longer lived species such as western larch.

Seral lodgepole pine stands are never remote from the seed of species that can replace them.

Reaction to competition.--Lodgepole pine is a shade-intolerant species (3). It is more intolerant than any of its main associates except western larch, which is even more intolerant, and ponderosa pine, which is about as tolerant. However, despite its intolerance, which is most pronounced at early ages, lodgepole pine can maintain itself in extremely dense stands for as long as 80 to 100 years. .

For good growth lodgepole pine requires more moisture in the soil and air and a lower average temperature than Douglas-fir and ponderosa pine, but probably less moisture and a higher temperature than Engelmann spruce and alpine fir (58). Under exposed conditions lodgepole pine is at a disadvantage compared to ponderosa pine. It not only has a greater leaf area per unit of weight than ponderosa pine, but in windy atmosphere its water loss per unit of leaf area is four times greater (25).

Release.--Growth response to release by thinning is not certain and appears to be related to such factors as site, age, original stand density, and severity of thinning. Several stands have shown good response to heavy thinning at an early age (2, 39, 48, 52). Others have shown no release when thinned at ages as young as 14 years.9/ Evidence indicates that once stagnation has set in it may be difficult to overcome. Thinnings at an age as early as 7 years might need to be made if immediate release is expected (51).

At older ages, growth response to release is correlated strongly with crown size and vigor and the amount of release given (63).

9/ Written communication from D. I. Crossley, Alberta, Canada, dated September 24, 1956.

INJURIOUS AGENCIES

Insects.--The most serious insect enemy of lodgepole pine is the mountain pine beetle (Dendroctonus monticolae). This insect has caused extensive losses in both the United States and Canada. Occasional epidemics have virtually wiped out thousands of acres of this species. Trees from 4 inches in diameter up to the largest size have been attacked. During epidemics trees are attacked irrespective of their health or vigor. The beetles enter mainly along the bole from a few feet above ground up to the middle branches but may also attack the larger limbs and the entire main stem, excepting the extreme top (35). In seedling and sapling stands, such as those that have developed in block clear cuttings, this beetle should not cause much concern.

The lodgepole pine beetle (Dendroctonus murrayanae), a much less aggressive insect than the mountain pine beetle, attacks old or weakened trees at the base (35). Because it may develop in large numbers in freshly cut stumps, it may become troublesome in old growth along the edges of improvement cuttings or other types of partial cuttings.

In young stands the lodgepole terminal weevil (Pissodes terminalis) at times causes great damage by attacking the terminal shoot and causing distorted or forked trees (20, 35). It is particularly destructive in young open-grown stands in California.

The principal defoliating insects are the lodgepole needle miner (Recurvaria milleri), the lodgepole sawfly (Neodiprion burkei), and the spruce budworm (Choristoneura fumiferana).

Diseases.--Dwarfmistletoe (Arceuthobium americanum) is widespread throughout the lodgepole pine type and causes a large but as yet undetermined amount of growth loss (68). Reproduction that develops beneath infected overstory is most likely to become infected. Dwarfmistletoe appears to increase its vigor and "broom out" when partial cutting is practiced. Because of its prevalence in the lodgepole pine type, silvicultural management of the species must be positively geared to its control.

Three stem rusts and several heart rot and root rot fungi cause mortality and cull in lodgepole pine. The comandra rust (Cronartium commandrae) is the most important rust because it causes widespread mortality in trees of all ages. Western gall rust (Peridermium harknessii), which occurs throughout the tree's range, causes considerable mortality to seedlings and causes bole deformity and breakage in older trees. P. stalactiforme causes some mortality, but is considered important principally because bole infections ruin living trees for either lumber or pulpwood (10, 39, 50).

The heart rot fungi, Fomes pini and Stereum pini, probably cause most cull in lumber trees, but several other stem, butt, and root rot fungi are important decay organisms (10, 50).

A branch of lodgepole pine heavily infected with dwarfmistletoe.

Fire.--Although serotinous cones can be opened by heat from fire and can withstand fire to some degree, they can also be consumed by fire. When this occurs the seeds necessary for regeneration are destroyed. Because of its relatively thin bark the tree itself is more susceptible to fire than Douglas-fir and any of the other pines with which it grows, but is less susceptible than Engelmann spruce and subalpine fir (39). Lodgepole pine trees killed by fire or insects may remain standing for 20 or more years. Standing dead trees decay slowly but often check so badly that merchantable lumber cannot be sawed from them (7).

Wind.--Because of its root habit lodgepole pine generally is considered susceptible to windfall, although, as with other species, its windfirmness varies with topography, soil conditions, and stand density. In many areas it is relatively windfirm, except where it develops shallow roots because of impermeable layers and excessively shallow, stony soils.

Animals.--Porcupines (Erethizon epixanthum) damage or completely girdle many trees. However, their destructiveness in relation to management of this species has not been determined.

Dwarfmistletoe brooms become abundant in infected stands which have been partially cut. The parasite eventually spreads to uninfected residual trees and its seeds shower down annually infecting young reproduction.

SPECIAL FEATURES

The volatile oil (turpentine) from the oleoresin of lodgepole pine consists largely of phellandrene, an unstable terpene having a boiling point higher than that of ordinary turpentine (54). Until recently this compound was reported as occurring in only one other species of pine--Coulter pine (Pinus coulteri) (45). Now it is known that phellandrene also makes up a small percentage of the oleoresin of the following pines:[10/] P. caribaea (5 percent), P. elliottii var. densa (19 percent), P. insularis (7 percent), Santa Cruz race of P. ponderosa (7 percent), and possibly P. resinosa (7 percent).

Lodgepole pine is a survivor from the Tertiary age in Yellowstone National Park. Knowlton (27, p. 667) found in Tertiary deposits in the park a fossil serotinous cone from a tree that he believed was the immediate ancestor of the lodgepole pine of today and later named Pinus premurrayana. Numerous other tree species that grew in the park during the Tertiary age have disappeared, mainly as a result of climatic change. The predominance of the lodgepole pine type over other contemporary forest types in this area attests its ability to withstand repeated fires.

RACES AND HYBRIDS

Evidence of climatic races of the inland form has been reported (66). Seed size varies in different parts of the range; the largest seeds are found to the south (Sierra Nevada). Seed planted in Finland from nine Canadian sources produced trees that varied in form, growth rate, and disease resistance. In Sweden, better trees were produced from seed from an Alberta, Canada provenance than from Colorado or Montana sources. After storage at low temperature, seed from warmer climates germinates more slowly than that from colder climates. Seed from higher elevations germinates better at low temperatures (66° F.) than seed from lower elevations. Correspondingly, seed from lower elevations germinates better at higher temperatures than high-elevation seed (26).

The most recent study of morphological and physiological variation in lodgepole pine (14) provides additional evidence of regional differentiation within the species. According to the author there are enough differences to justify separate taxonomic recognition to four groups of lodgepole pine. He designates these groups' subspecies, as follows:

Coastal group: Pinus contorta Douglas ex Loudon ssp. contorta
Mendocino white plains group: Pinus contorta ssp. bolanderi (Parl.) stat. nov.
Sierra Nevada group: Pinus contorta ssp. murrayana (Balf.) stat. nov.
Rocky Mountain group: Pinus contorta ssp. latifolia (Engelmann ex Watson) stat. nov.

10/ Written communication from Pacific Southwest Forest and Range Experiment Station, Berkeley, California, dated December 15, 1960.

Within some parts of the species distribution certain character gradients, or clines, are also expressed. Whether these gradients are environmental or whether they are genetically controlled has not been determined. Most of the morphological characters studied vary somewhat regularly with elevation but not with latitude. A summary of the main characters and their indicated variability is given in table 1.

Natural hybrids of lodgepole pine with jack pine (Pinus banksiana) are found in Alberta, Canada (47). Crosses between these two species can also be made by controlled pollination (53).

Table 1.--Variation in certain morphological characters for natural populations of lodgepole pine by geographic regions[1, 2/]

Character	Coast regions		Inland regions	
	Coastal	Mendocino white plains	Sierra Nevada	Rocky Mountains
Cone specific gravity	Shows greatest regularity in variation pattern and clearest distinctions between geographic regions of any character. Sample mean range 0.50 to 0.79; tree mean range 0.43 to 0.89.			
	Intermediate 0.62 to 0.69	High 0.71 to 0.77	Low 0.50 to 0.67	High 0.64 to 0.79
Cone angle of attachment (mature cones)	Greatest variability in eastern parts of species range (Rocky Mountains), diminishing away from this zone. Sample mean range 81° to 139°; tree mean range 44° to 153°; individual cone range 30° to 170°.			
	Less variable; mostly reflexed	Less variable; mostly reflexed	Less variable; predominantly projecting or only slightly reflexed. Decreasing irregularly from north to south in Cascades and Sierra Nevada. Least variable in south Sierra Nevada (80° to 100°)	Variable; suberect, protruding or reflexed.
Cone symmetry	Variable throughout range. Maximum symmetry in Sierra Nevada. Maximum asymmetry associated with high specific gravity and large angles of attachment (reflexed cones)			
Leaf width	Mean width 1.5 to 1.6 mm. Range 1.0 to 2.5 mm. No absolute relationship with elevation for species in its entirety.			
	Uniformly near average 1.4 to 1.6 mm.	Uniformly narrow; about 1.3 mm.	Variable; elevational clines expressed. Sierra Nevada wider than Rocky Mountains at comparable elevations	
Leaf length	Sample mean range 3.1 to 7.1 cm.; tree mean range 2.4 to 8.9. Generally shorter with coastal sources than inland sources but much overlapping in size.			
Leaf resin canal frequency	Number ranges from 0 to 7; majority of leaves have 0, 1, or 2. Sample mean range 0 to 2.1; tree mean range 0 to 3.9.			
	Wide range; number increases from south to north. Includes extremes in number for entire species. None in Mendocino County, California	None. (Unique in the genus Pinus)	Wide range	Wide range
Stomatal subsidiary cells	Striking regional differences are exhibited in the shape of the flange (thickest portion of the subsidiary cell wall which controls the size of the outer opening of the epistomatal cavity), the shape of the epistomatal cavity, and the size of the outer aperture. The heritable nature of subsidiary cell shape is indicated by similar differences in plantation samples.			

1/ Based on Critchfield (14).

2/ Definition of geographical regions:

Coastal	Entire coastal distribution except Mendocino white plains
Mendocino white plains	Plateau area of highly acid hardpan soil along Mendocino County coast
Sierra Nevada	Sierra Nevada proper, Siskiyou Mountains, and Oregon Cascades
Rocky Mountain	Entire inland distribution except Sierra Nevada geographical region

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